2024

SOIL OF THE YEAR

Forest soil

Soil of the Year 2024 in Germany – Forest Soil

Almost one third of the area of Germany (11.4 million hectares) is covered by forest. Thus, forest soils play an important role in our landscape, providing fundamental functions and ecosystem services to forests and their water and nutrient cycles.

Figure 1 Forest covered area of Germany.

Forest soils offer sites for plant growth and provide nutrients; as such they are the basis of productive forests that are able to adapt to environmental changes. Being carbon reservoirs, forest soils also contribute to climate-change mitigation; moreover, they ensure clean drinking water and water retention during extreme rainfall events. Forest soils buffer air-borne deposition of pollutants and acids and serve as a habitat for a large variety of organisms.

Forest soils are influenced not only by climate, geology and their position in the landscape, but also by tree species composition. In turn, all tree species depend on certain soil properties. Forests cannot exist at sites that are too wet or too dry. Climate change will thus affect the natural distribution of tree species and forestry options in the future.

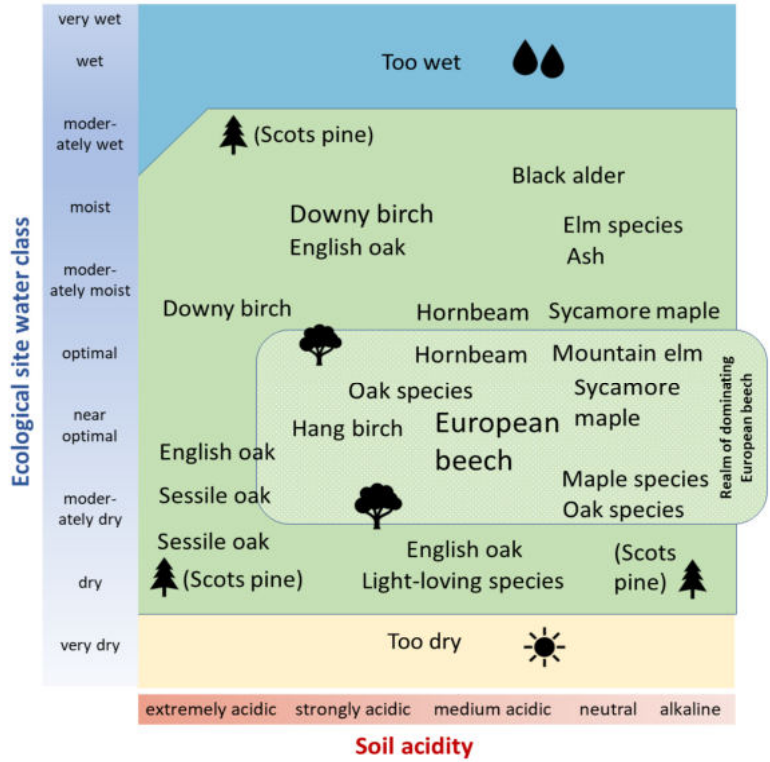

Figure 2
Ecogram showing natural abundance of different tree species depending on water availability and soil acidity (lower mountainous elevation zone). © Thünen Institute of Forest Ecosystems according to Liebscher modified according to Leuschner.

Representative profile Soil of the Year 2024

An acidic and nutrient-poor Stagnosol (Pseudogley according to the German soil taxonomy) in the Tharandt Forest near Dresden was selected to represent the diversity of forest soils. Stagnosols are among the soils characterized by perched water. This soil group is the second most common one on NFSI (National Forest Soil Inventory) sites.

In this soil profile, a compacted subsoil leads to long-lasting waterlogging, which can extend up to the soil surface in rainy years. Because of a lack of oxygen and the dense subsoil, the root zone of the spruce stand at this site is extremely shallow. This results in increased susceptibility to windthrow and drought stress in years with little rainfall. English oak and hornbeam would be more suitable tree species at such sites.

Figure 3.
© Janis Kreiselmeier, Thünen Institute of Forest Ecosystems

Mull, moder and mor – the humus layer with higher or lower biological activity

When leaves, needles and twigs fall onto the forest floor as litter, they form a humus layer together with other organic remains. Depending on the ecological site conditions, different humus forms, such as mull, moder or mor, develop over time. The actual humus form points to the magnitude of biological activity and nutrient turnover, as well as to the nutrient availability in the topsoil. The humus form that develops at a certain site, depends on the temperature, water availability, aeration, nutrient supply, litter composition and the activity of the soil organisms.

Figure 4
Three typical forest soils with their characteristic humus forms, from left to right: Luvisol with mull, Cambisol with moder, Podzol with mor.
© Rüdiger Süß, ThüringenForst and Markus Weise, Sachsenforst.

Mull indicates high biological activity and high nutrient supply. Litter material is quickly decomposed by soil organisms, and the obtained fine humus is mixed into the soil by burrowing animals such as earthworms.

Moder develops from litter that is less easily decomposable on soils that tend to be acidic. Soil life is restricted. The name 'moder' comes from the musty smell when wet, caused by fungi.

Mor (raw humus) can be found on very acidic soils under coniferous forests with dwarf shrubs such as blueberry or heather. The litter of these plants is rather persistent. Thus, its decomposition proceeds slowly and remains incomplete.

The diversity beneath our feet

Different from what the term “forest soil” might suggest, there is not one forest soil. In contrast, a great variety of soil types with diverse properties and appearance is found underneath our forests.

Figure 5
Diverse appearance of forest soils. Factors controlling soil formation, properties and functionality include bedrock, climate, flora and fauna, as well as human influence and the duration of soil formation.
© Thünen Institute of Forest Ecosystems.

Braunerden (mainly Cambisols, some classifying as Arenosols, Umbrisols, Phaeozems) are the most widespread forest soils in Germany. The key soil-forming processes that are eponymous for these soils are weathering and brunification, the latter resulting from the formation of iron compounds that give the soils their brown to reddish-brown color.

Stauwasserböden (Stagnosols, some classifying as Planosols) are present at 10 % of the NFSI sites. They are characterized by temporary excess of water causing a lack of oxygen. Forest communities such as English oak-hornbeam forests can cope well with this situation and are growing at these sites.

Podzols are nutrient-poor and acidic soils. The word Podzol, 'ash soil', comes from the Russian language. Organic acids are released from the humus layer above the mineral soil and percolate through the topsoil, thereby taking up humic substances, iron compounds and nutrients, and transporting these compounds down to the subsoil. This process results in a light color of the humus- and iron-depleted topsoil that led to the name 'ash soil'. Podzols are mainly found under heath and coniferous forest.

Lessivés (Luvisols, Alisols, and Retisols) are soils characterized by clay migration from the topsoil to the subsoil. They are usually suitable for agriculture. Nevertheless, they make up 8 % of the forest soils at NFSI sites.

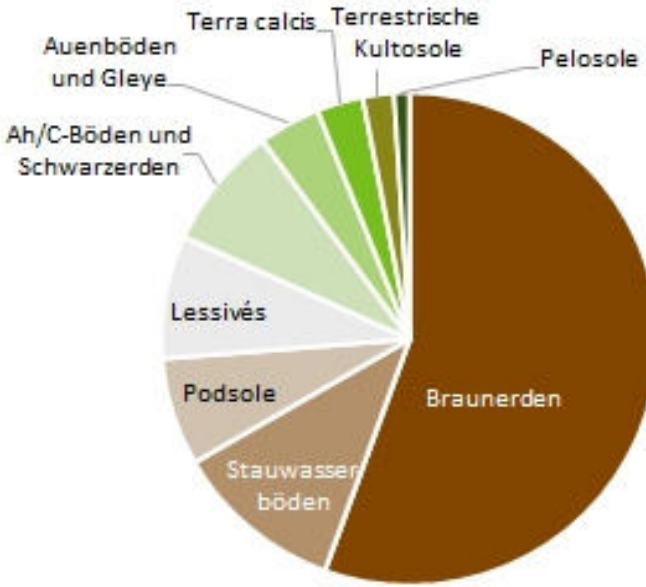

Figure 6
Frequency of soil classes (German soil taxonomy) at the approximately 1,900 sites of the second National Forest Soil Inventory (NFSI). © Thünen Institute of Forest Ecosystems.

[Rough correlation of German soil classes to Reference Soil Groups according to the World Reference Base 2022: Braunerden = Cambisols, some classifying as Arenosols, Umbrisols, Phaeozems; Stauwasserböden = Stagnosols, some classifying as Planosols; Podsole = Podzols; Lessivés = Luvisols, Alisols, and Retisols; A/C-Böden incl. Schwarzerden = Leptosols, Regosols, Phaeozems, Chernozems; Auenböden und Gleye = Fluvisols, Fluvic Cambisols, and Gleysols; Terrae calcis = Cambisols, some classifying as Phaeozems; Terrestrische Kultisole = Anthrosols, Phaeozems, Cambisols, Regosols; Pelosole = Vertisols]

Histosols and other wet soils rich in humus

The proportion of Histosols (i.e., peat soils) and other humus-rich wet soils in the soil cover under forest is approximately 2.4 %. The major part of the peatland and wet soils has been subject to artificial drainage. Even though Histosols make up only a small area, they act as an important carbon storage, and as a relevant CO_2 source in case of drainage. Their rewetting offers potential for climate-change mitigation and biodiversity conservation.

Figure 7
Drained Histosol (Sapric Murshic Histosol (Dystric)) with tree-root remains in the Ore Mountains. © Nora Pfaffner, Thünen Institute of Forest Ecosystems.

How is the forest soil doing? – Results of the National Forest Soil Inventory (NFSI)

The **National Forest Soil Inventory (NFSI)** provides information about the current state and the changes of our forest soils. For this purpose, **soil, forest-stand and vegetation data are collected on 8 km x 8 km grids at 1,900 sites across Germany.** The NFSI takes place approximately every 15 years. The field assessments of the third NFSI are currently in progress.

Figure 8 The forest floor and intensively rooted topsoil: the place where organic matter is transformed, most of the soil organisms live and where nutrients are recycled.
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Forest soils contribute to climate-change mitigation

Forest soils of Germany contain more than 1 billion tons of carbon (C) down to a depth of 90 cm. With this, they represent the second largest carbon storage in our forest, next to the (living) plant biomass. Between 1990 and 2012, an estimated 0.4 t of C per ha and year has been accumulated in the mineral soil, while the organic layer above the mineral soil lost about 0.02 t C per ha and year over the same period.

Water storage under pressure

Many forest soils severely dried out during the drought years 2018 to 2020. At many sites, spruce stands, weakened by the series of droughts, were attacked by bark beetles and finally died off.

Figure 9
Dead standing Norway spruce, National Park Harz. © J. Evers.

Nutrient depletion through wood harvesting

On nutrient-poor sites, timber harvesting can lead to a nutrient export that exceeds the amount of nutrients replenished in the soil through weathering. This is evident, for example, in the lack of phosphorus in some beech stands.

Heavy metal levels are decreasing

Due to very high regional air pollution in the past, heavy metals accumulated in the topsoils of forests. Meanwhile, the levels have decreased but remain critical in some places for lead and arsenic.

Nitrogen deposition is too high

At many sites, the critical load of forest soils for the important plant nutrient nitrogen is significantly exceeded. Nitrogen stocks in topsoils are increasing due to atmospheric input. This has led to an oversupply in the needles and leaves over the last decades. It may also cause nitrate leaching into the groundwater.

Air pollution control and liming reduce soil acidification

Major efforts in air pollution control and regional soil protective liming since the 1980s have noticeably counteracted the acidification of forest soils. Forest soils have experienced a general slight increase in soil pH since 1990.

pH H_2O, 80 % of NFSI samples (2007)		
Soil zone	pH min.	pH max.
Organic layer	3,7	5,7
0 - 05 cm	3,6	5,8
05 - 10 cm	4,0	5,6
10 - 30 cm	4,2	5,0
30 - 60 cm	4,3	5,3
60 - 90 cm	4,7	5,8

Figure 10
Soil protective liming by helicopter, © Geological Survey North-Rhine Westphalia.

Bundesministerium für Ernährung und Landwirtschaft

The Soil of the Year 2024 in Germany was proclaimed on World Soil Day 2023 in the venue of the Ministry of Food and Agriculture in Berlin. The Federal Minister Cem Özdemir has taken the patronage of the "Soil of the Year" campaign. He welcomed more than 200 participants.

THÜNEN

Editor
Thünen Institute of Forest Ecosystems in cooperation with the Steering Committee Soil of the Year (German Soil Science Society - DBG, German Soil Association - BVB, German Engineer Association for Management of Contaminated Soils and Land Recycling - ITVA.

More information

National Forest Soil Inventory (NFSI)

National Peat Inventory
Forest Sites

Steering Committee
Soil of the Year
Web page

German Environment Agency (UBA)